MEASUREMENTS REPORT: THERMAL PROPERTY MEASUREMENTS OF MANNED SPACECRAFT CENTER SPACESUIT MATERIALS

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I. INTRODUCTION

TRW Thermophysics Section Laboratory personnel have measured the thermal radiation properties of five spacesuit materials as requested. Materials measured and the measurements taken are listed in Table I. The total hemispherical emittance measurements of Lexan coated with LEV 31 and Lexan coated with LEV 32 were stopped because of sample-heater bonding failure, i.e., the test material separated from the heater at the higher test temperatures. Additional tests at the higher temperature will be completed when additional test material is submitted. All of the test materials used were submitted by the customer.

The Beta Cloth and Chromel "R" samples, serial numbers 218-67 and 1209-67, respectively, were remeasured at the request of J. Poradek. Remeasurement was requested because of previously reported differences (approximately 10%) between the integrating sphere and the paraboloid in the 2.0 to 2.5 micron region. Results of these measurements are included here along with the other measurements requested.

II. METHOD OF MEASUREMENT

A. SOLAR REFLECTANCE

The near-normal directional spectral reflectance properties of the test sample were measured over the wavelength interval extending from 0.28 to 2.5 microns. These measurements were taken in an integrating sphere reflectometer similar to that described by Edwards, et al[1]. Solar reflectance was calculated by integrating the reflectance data over the Johnson[2] solar energy distribution. Solar absorptance was calculated by subtracting the solar reflectance from unity.

B. NORMAL EMITTANCE

Near-normal emittance was calculated from directional spectral reflectance measurements taken over the spectral band from 2.0 to 26.0 microns. Measurements were taken with the TRW Paraboloid Relative

Reflectometer[3]. Emittance was calculated by integrating the reflectance data over the 300°K Planckian distribution and subtracting the integral from unity.

C. SOLAR TRANSMITTANCE

The near-normal transmittance was measured by placing the test sample at the entrance port of an integrating sphere reflectometer of the type described by Edwards.[1] The solar transmittance was calculated by numerically integrating the spectral transmittance over the Johnson[2] solar energy spectrum.

D. TOTAL HEMISPHERICAL EMITTANCE MEASUREMENT

The Beta Cloth sample was prepared for measurement by cementing the material to a heater assembly. Minnesota Mining and Manufacturing Company (3M) Adhesive Transfer Tape - Type 467 was used for this purpose.

The heater element consisted of a constantan wire (40 gauge) resistor sandwiched between two pieces of 0.013 cm thick Mylar (polyethylene terephthalate). Next, this heater was cemented between two sheets of aluminum (Type 1100 soft) 10 cm square by 0.05 cm thick. The cement employed for this purpose was Shell Epon 828 activated with Shell Epon Curing Agent V40. Thermocouples were attached to the sample surfaces with small drops of Barco Bond MB-165, 60-second epoxy. The completed assembly measured approximately 10 cm (four inches) square by 0.25 cm (0.098 inch) thick.

The sample-heater assembly was suspended by the heater and thermocouple leads within a blackened liquid nitrogen cooled enclosure. Pressure within the enclosure was reduced to 10^{-6} torr or less. Nominal sample temperatures of -.25°F (-87.2°C), 0°F (-17.8°C), +150°F (+65.6°C), and +250°F (121.1°C) were set by adjusting the electrical power supplied to the sample heater. Equilibrium was determined by monitoring thermocouple readings. Measurements used for determining emittance were not acceptable until constant for a 20 to 40 minute time interval. The technique described above is that given by Nelson and Bevans[4].

III. MEASUREMENT RESULTS

A. SOLAR ABSORPTANCE

TRW LABORATORY S/N	MATERIAL	SOLAR ABSORPTANCE (α_s)
108-68	Teflon Coated Beta Cloth	0.21_6
1218-67	Uncoated Beta Cloth	0.19_2
1209-67	Chromel "R"	0.71_6
269-68	Lexan Coated with LEV 32	0.41_1

B. NORMAL EMITTANCE

TRW LABORATORY S/N	MATERIAL	SAMPLE TEMPERATURE (^oK)	NORMAL EMITTANCE (ϵ_N)
108-68	Teflon Coated Beta Cloth	300^o	0.92_2
1218-67	Uncoated Beta Cloth	295^o 397^o	0.93_8 0.93_4
1209-67	Chromel "R"	290^o 387^o	0.43_1 0.43_6
268-68	Lexan Coated with LEV 31 (Coated Side)	300^o	0.10_5
269-68	Lexan Coated with LEV 32 (Coated Side)	300^o	0.06_4
269-68	Lexan Coated with LEV 32 (Uncoated Side)	300^o	0.93_4

C. SOLAR TRANSMITTANCE

TRW LABORATORY S/N	MATERIAL	SOLAR TRANSMITTANCE (τ_s)
268-68	Lexan Coated with LEV 31 (from uncoated side)	0.51_2
269-68	Lexan Coated with LEV 32 (from Uncoated Side)	0.10_6

D. TOTAL HEMISPHERICAL EMITTANCE

TRW LABORATORY S/N	MATERIAL	TEMPERATURE (°F)	(°C)	EMITTANCE (ϵ_H)
104-68	Teflon Coated Beta Cloth	-125.5°	-87.5°	0.874
		- 3.1°	-19.5°	0.851
		+145.04°	+62.8°	0.924
		+241.88°	+116.6°	0.934

Data taken on the Lexan (with LEV coatings) prior to sample failure are tabulated below.

TRW LABORATORY S/N	TEST MATERIAL	TEMPERATURE (°F)	(°C)	EMITTANCE (ϵ_H)
105-68	Lexan Coated with LEV 31	-122.98°	-86.1°	0.167
		- 3.28°	-19.6°	0.171
		+150.08°	+65.6°	0.186
106-68	Lexan Coated with LEV 32	-131.80°	-91.0°	0.093
		- 0.76°	-18.2°	0.095
		+143.06°	+61.7°	0.106

E. SPECTRAL DATA

Graphs of the spectral data are presented in Figures 1 through 8.

IV. DISCUSSION

Previously reported (TRW Report No. 67-3346.11ja-83) Chromel "R" data displayed a difference of several per cent between short and long wavelength measurements in the spectral overlap region, i.e., the region extending from 2.0 to 2.5 microns. An investigation of this overlap region discrepancy has confirmed the validity of the results previously reported. The difference resulted from the use of different samples for measurements taken in the short (0.28 to 2.5 microns) and long wavelength (2.0 to 26.0 microns) spectral regions. Sample S/N 1209-67, used in the 2.0 to 26.0 micron region appears much darker than sample S/N 671-67 and apparently was taken from a seam area where it had been flexed numerous times. Consequently, for purposes of the present measurements, only one sample (S/N 1209-67) was used for both the short and long wavelength measurements. Results of these measurements agree, in the overlap region, within the accepted tolerances (±0.015%) for these measurements.

The beta cloth data shown in Figure 3 shows a difference in measured reflectance in the 2 to 2.5 micron region between the paraboloid and integrating sphere. These measurements were made using identical sample configurations: two layers of beta cloth backed by an aluminum disc. Differences in measured values are probably due to slight differences in geometry. The integrating sphere sample beta cloth was taped flat on a holder, while the paraboloid sample was held by a retaining nut and became slightly "puffed" when tightened. This implies that rays are scattered more, hence more absorption in the "puffed" sample. This may be the case for the actual suit configuration and should be considered when calculating heat inputs.

V. REFERENCES

1. Edwards, D. K., et al., "Integrating Sphere for Imperfectly Diffuse Samples," Journal of the Optical Society of America, Volume 51, pp. 1279-88 (November 1961).

2. Johnson, F. S., "The Solar Constant," Journal of Meteorology, Volume 11, pp. 431-439 (December 1954).

3. Neher, R. J. and Edwards, D. K., "Far Infrared Reflectometer for Imperfectly Diffuse Specimens," Applied Optics, Volume 4, pp. 775-779 (July 1965).

4. Nelson, K. E. and Bevans, J. T., "Errors of the Calorimetric Method of Total Emittance Measurement," Measurement of Thermal Radiation Properties of Solids, NASA SP-31, 1963.

TABLE I

TRW Laboratory S/N	
1209-67	Chromel "R" (Hoskins Munufacturing Company trade name for a nickel-chromium alloy containing 74% nickel and 20% chromium). The sample was cleaned Freon TF Precision Cleaning Agent (DuPont) prior to measurement.
1218-67	Beta Cloth (Owens Corning trade name for their fiberglass cloth). The sample was composed of two layers of Beta Cloth backed by an aluminum disc.
104-68	Teflon coated Beta Cloth - one layer over three layers of aluminized Kapton (aluminized side out).
108-68	Teflon coated Beta Cloth - one layer over three layers of aluminized Kapton (aluminized side out)
268-68	Lexan coated with Perkin Elmer LEV 31.
269-68	Lexan coated with Perkin Elmer LEV 32.

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER COD. NO.:
TRW DESIGNATION: 108-68
MATERIAL: Teflon Coated Beta Cloth

ANGLES
POLAR, θ 15°
AZIMUTHAL, φ 0°

MEASUREMENT: Reflectance versus Wavelength
INSTRUMENTS: 0.28 to 2.5μ - Beckman Spectrophotometer
2.0 to 26μ - TRW Paraloid Relative Reflectometer

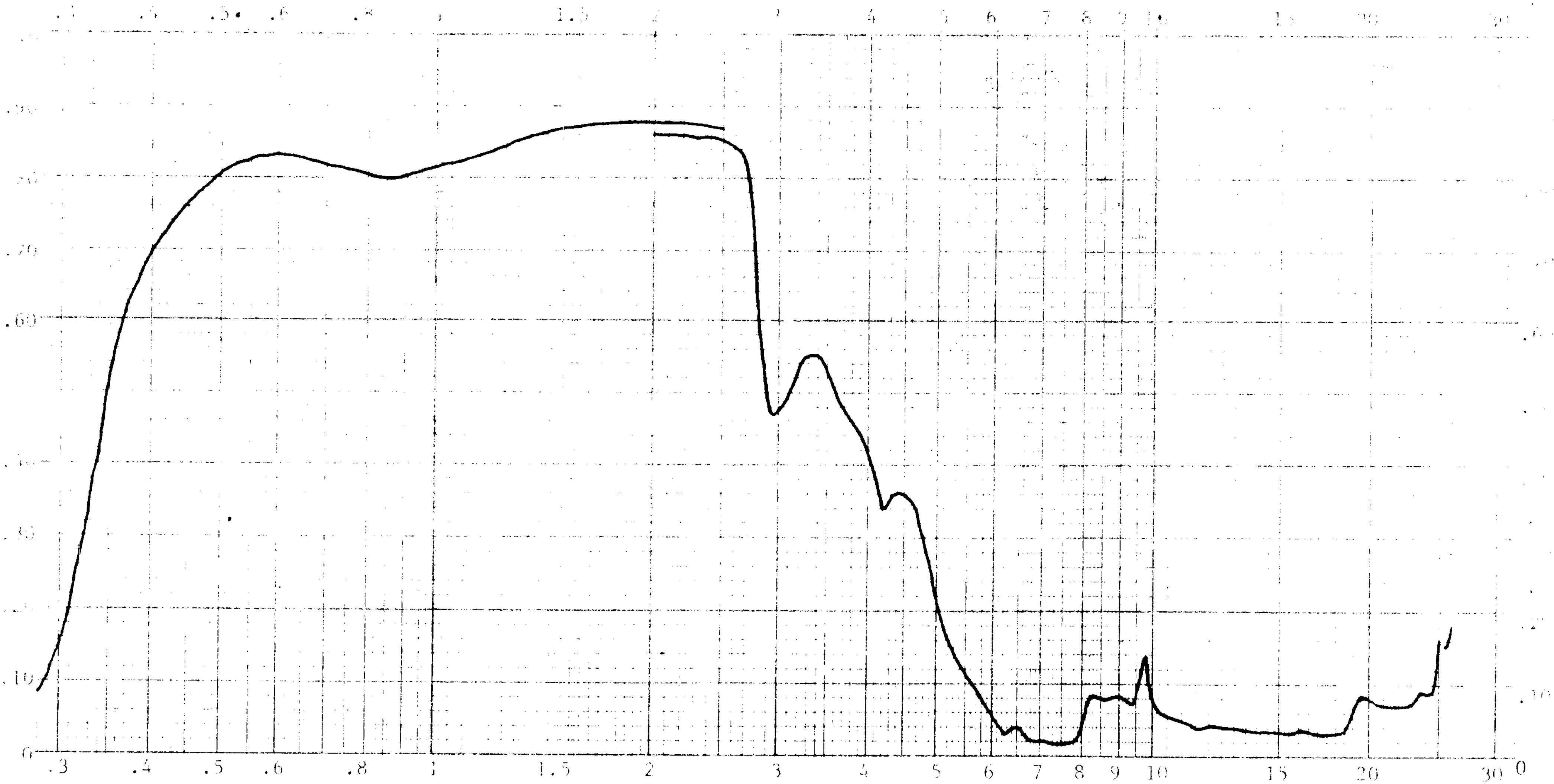

Figure 1

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 1209-67

MATERIAL: **Chromel "R"**

ANGLES

POLAR, $\theta =$ 15°

AZIMUTHAL, $\phi =$ 0°

MEASUREMENT **Reflectance versus Wavelength**

INSTRUMENTS

.28 - 2.5μ - **Beckman Spectrophotometer**

2.0 - 26.0μ- **TRW Paraboloid Relative Reflectometer**

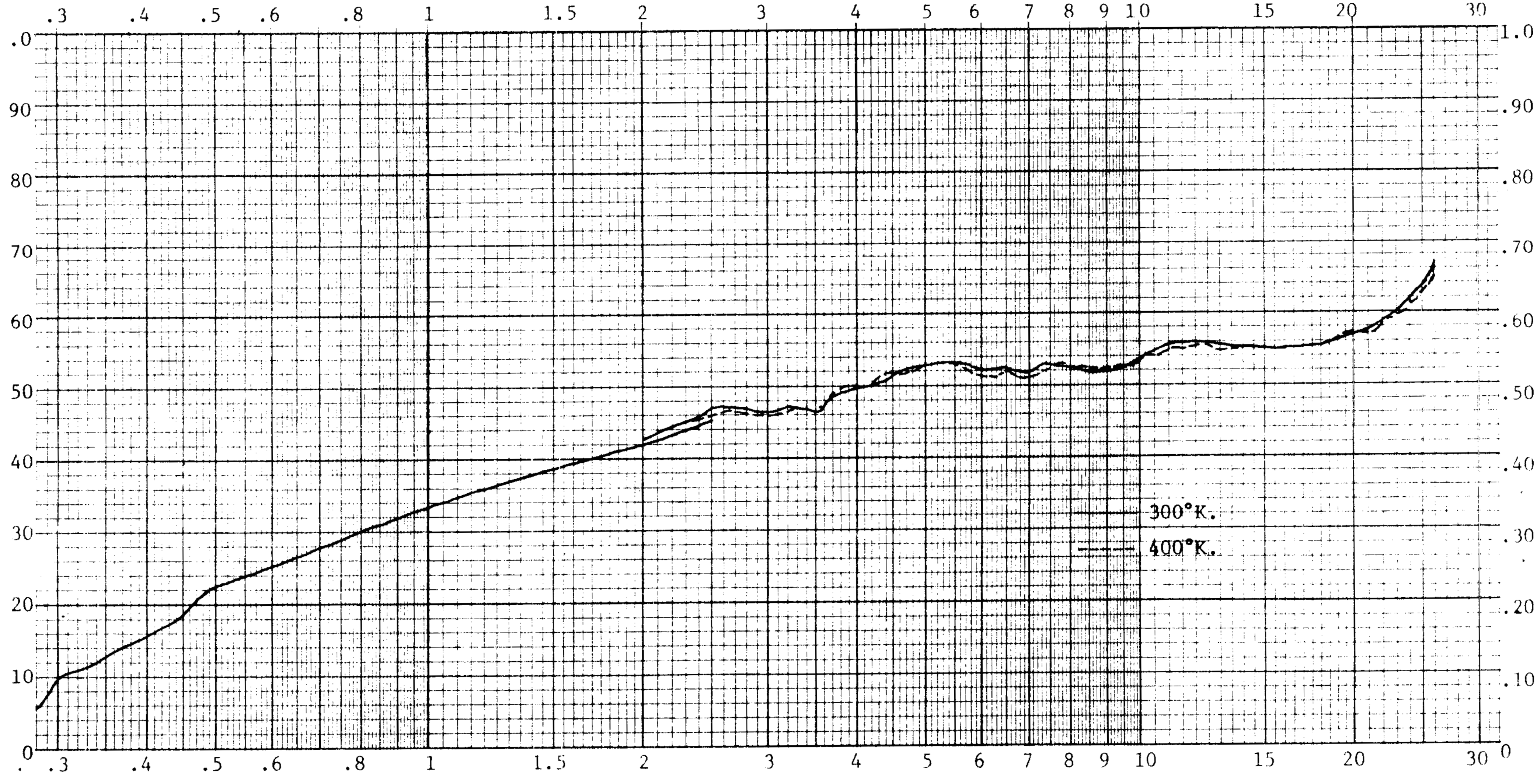

Figure 2

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 1218-67

MATERIAL: Beta Cloth

ANGLES

POLAR, θ= 15°

AZIMUTHAL, ϕ= 0°

MEASUREMENT Reflectance versus Wavelength

INSTRUMENTS
0.28 - 2.5 μ - Beckman Spectrophotometer
2.0 - 26.0μ - TRW Paraboloid Relative Reflectometer

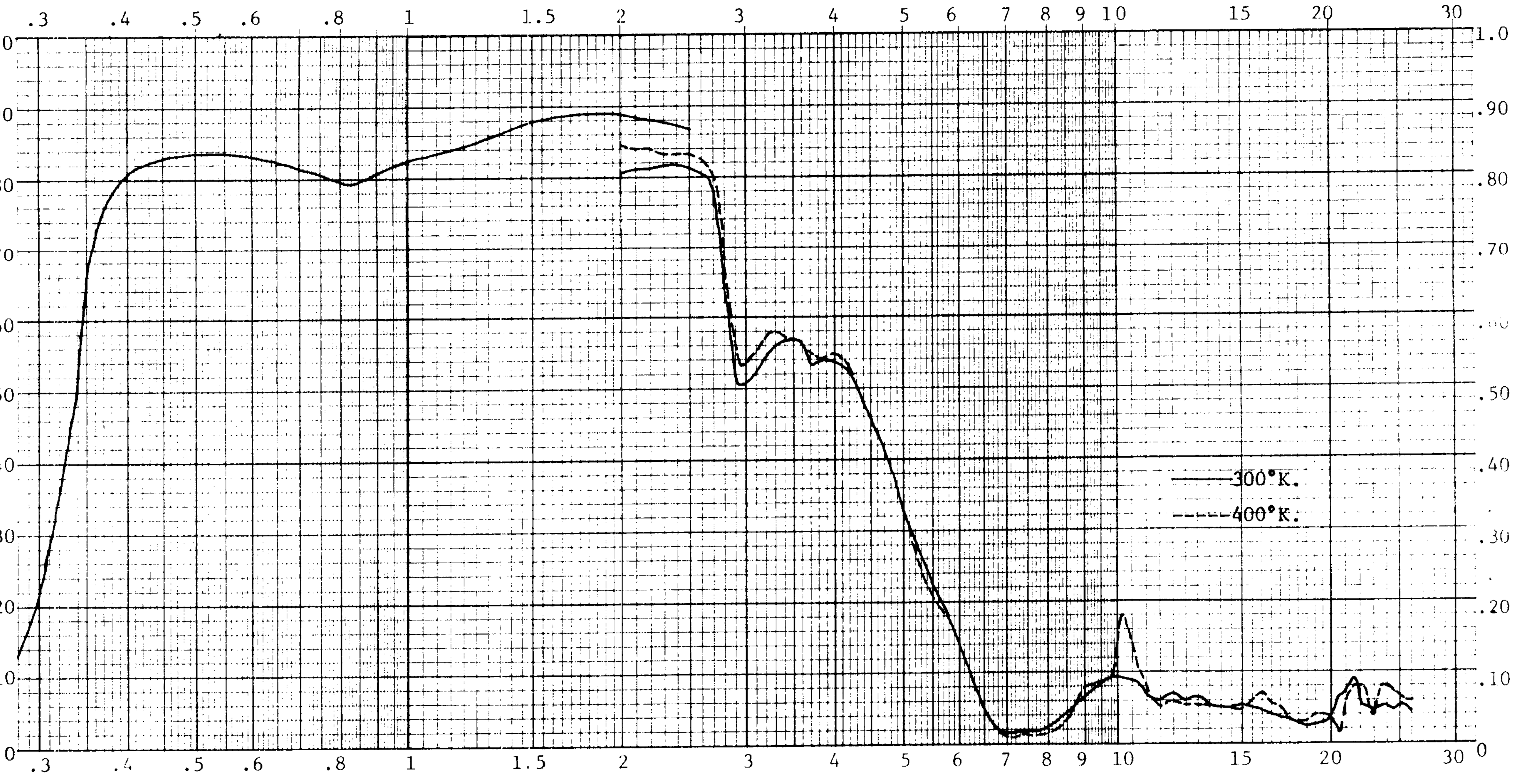

Figure 3

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 268-68

MATERIAL: **Lexan Coated with LEV 31**
Energy Incident on the Uncoated Side

ANGLES
POLAR, $\theta = 15°$
AZIMUTHAL, $\phi = 0°$

MEASUREMENT **Transmittance versus Wavelength**
INSTRUMENTS **Beckman Spectrophotometer**

WAVELENGTH (MICRONS)

Figure 4

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 268-68

MATERIAL: Lexan Coated with LEV 31
Energy Incident on the Coated Side

ANGLES
POLAR, $\theta = 15°$
AZIMUTHAL, $\phi = 0°$

MEASUREMENT Reflectance versus Wavelength

INSTRUMENTS TRW Paraboloid Relative Reflectometer

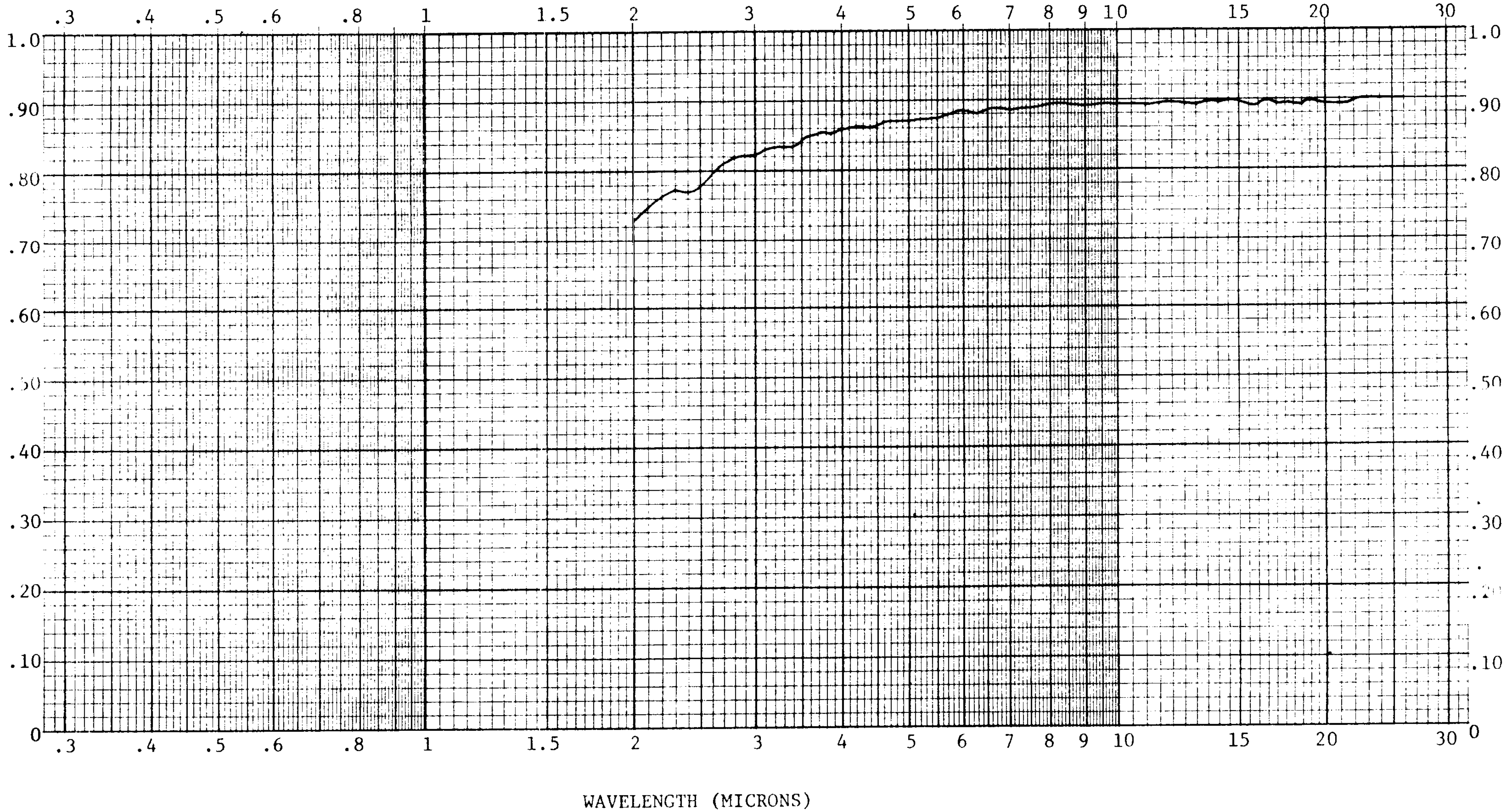

Figure 5

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 269-68

MATERIAL: Lexan Coated with LEV 32
Energy Incident on the uncoated side

ANGLES
POLAR, $\theta =$ 15°
AZIMUTHAL, $\phi =$ 0°

MEASUREMENT Reflectance versus Wavelength

INSTRUMENTS
0.28 - 2.5 μ - Beckman Spectrophotometer
2.0 - 26.0 μ - TRW Paraboloid Relative Reflectometer

Figure 6

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 269-68

MATERIAL: Lexan Coated with LEV 32
Energy Incident on Coated Side

ANGLES

POLAR, $\theta =$ 15°

AZIMUTHAL, $\phi =$ 0°

MEASUREMENT Reflectance versus Wavelength

INSTRUMENTS Paraboloid Relative Reflectometer

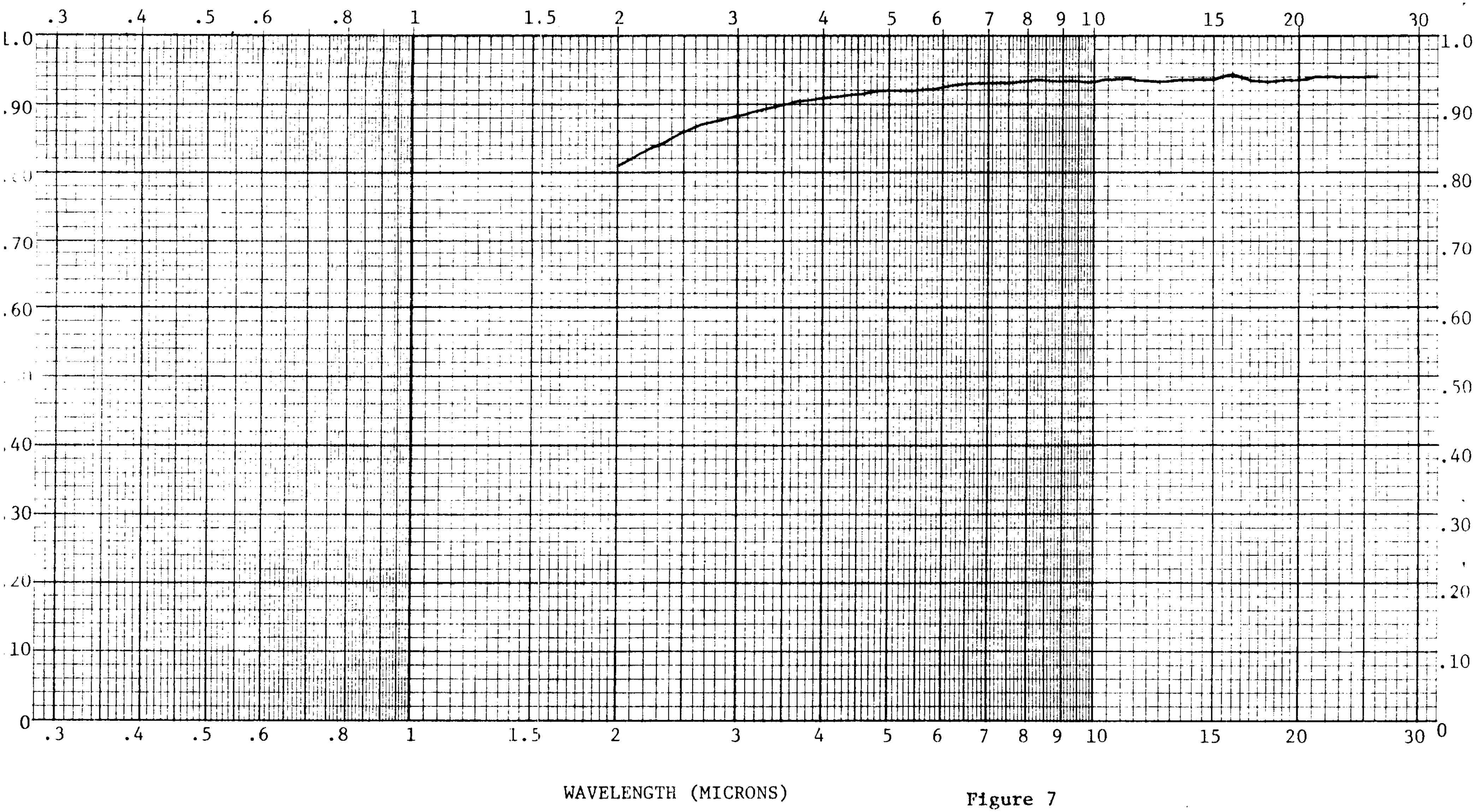

Figure 7

DIRECTIONAL SPECTRAL REFLECTANCE

CUSTOMER CODE NO.:

TRW DESIGNATION: 269-68

MATERIAL: **Lexan coated with Perkin Elmer** LEV 32
Energy Incident on Uncoated Side

ANGLES

POLAR, $\theta = 15°$

AZIMUTHAL, $\phi = 0°$

MEASUREMENT **Transmittance versus Wavelength**

INSTRUMENTS **Beckman Spectrophotometer**

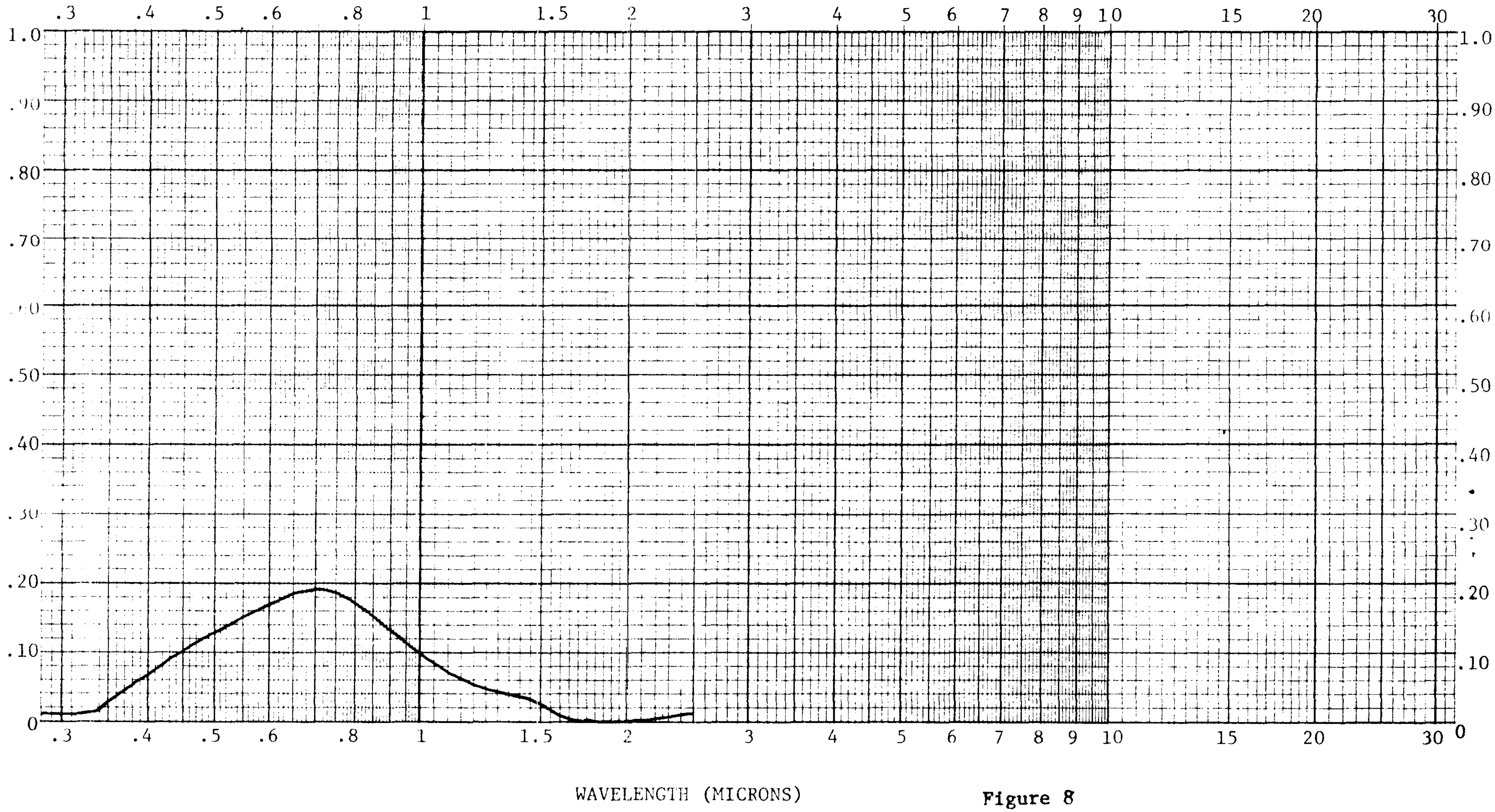

Figure 8